

CALFED Adaptive Management Workshop

March 19-20, 2002

Topic area report: Flow manipulation

Summary report

Prepared by Wim Kimmerer

Input by Brad Cavallo, Frank Ligon, Scott McBain, Craig Stevens, John Williams, Serge Birk

Introduction: The theme for this working group was the manipulation of flow in rivers and streams for the purpose of restoration. The group worked through consensus, which does not mean unanimity, and not all participants were entirely convinced of the outcome.

There was a tacit assumption that by “restoration” we were referring really to “rehabilitation”, since various obstacles exist to returning systems to a previous state. In addition, returning a system to natural in terms of flow and temperature may not be desirable: the natural habitat for several of the salmonid races in the Central Valley is inaccessible, so they must use artificially-created habitat such as cold water below dams.

The CALFED Ecosystem Restoration Program Strategic Plan listed six goals for restoration (more accurately, rehabilitation) of the estuary/watershed system, of which four are particularly relevant here. Paraphrased, these are:

1. Achieve recovery and increase populations of native species
2. Rehabilitate natural processes to favor native species with minimum ongoing intervention
3. Maintain and enhance populations of selected species for harvest
4. Protect or restore functional habitat types throughout the watershed

Flow manipulations for goals 1 and 3 typically target salmonids, although the flow manipulations may directly affect habitats for a variety of species and natural geomorphic and ecological processes. In other words, assumed benefits to salmonids of changes in flow may be direct (e.g., through improved habitat quality because of the higher flow) or indirect as a result of geomorphic or other physical alterations in habitat resulting from flow manipulations.

Many programs now exist in which river flow is adjusted or manipulated to achieve some perceived biological benefit. Most of these manipulations take the form of a mandated minimum instream flow below a dam. Several additional programs exist in which water can be acquired, through regulation or purchase, and used for environmental purposes. These include the Central Valley Project Improvement Act (CVPIA), which calls for up to 800,000 acre-feet of CVP yield to be used for environmental purposes; the Environmental Water Account (EWA), which purchases water (~400,000 acre-feet) for environmental purposes and conflict reduction, to date focused mostly on reduction of export flow in the Delta; and the Environmental Water Program (EWP), which is designed to purchase water for environmental purposes. Finally, the Vernalis Adaptive Management Program (VAMP) gets water from San Joaquin tributaries mainly through a FERC agreement, and uses the water in experimental manipulations of river flow and export flow in the Delta.

Few of these activities have provided convincing evidence of their efficacy. Although any stream has a minimum flow below which it ceases to support species of concern, in many cases

there is great uncertainty on the shape of the response of, e.g., salmonid smolt production to either the amount or the pattern of variability of flow. Instead, many of the regulatory minimum flows are set using models such as the Instream Flow Incremental Methodology (IFIM), which has proven a poor predictor of the flow dependence of either spawning or rearing habitat.

If the commonly-used methods fail to provide useful guidance, what restoration actions are supported by data? There is a general belief among biologists that flow is either too low or improperly timed in many streams in the Central Valley, and that more flow at certain times would be better for salmonids. The key uncertainty, though, is how much flow is needed and in what temporal pattern.

This situation is ideally suited to adaptive management, in which a restoration action (increased flow or modified flow regime) is conducted in a scientific framework where the ancillary objective is to understand better how the river ecosystem responds to flow. A well-designed action would increase populations of salmonids (if the prevailing view is correct), while the accompanying research and monitoring would disclose the magnitude of the increase, its mechanism and the magnitude of changes in intermediate variables such as egg deposition, and the form of the relationship between flow and the observed benefits. This information would then be used in a feedback loop to improve the way these flow releases are conducted. The feedback loop need not be based on adult abundance, since that can be affected by factors outside the region being manipulated.

In contrast to topics considered in the other groups, this topic lends itself to a more experimental framework. Since augmentation of flow must be continued to be successful as a restoration action, the opportunity exists to manipulate the flow to allow for contrasts in time. This is still restoration in that the net result is expected to benefit the ecosystem, but it can be done with more experimental flexibility than is available to actions requiring more structural change.

Flow manipulations satisfy all of the principles elucidated in the workshop description:

Scale dependence: By definition, most flow manipulations would occur on a large scale. Even relatively small changes in flows could produce measurable effects far downstream from the point of release. These effects could not be detected at the scale of a laboratory experiment, but only in a manipulation at the scale of at least a river reach if not an entire river.

Signal-to-noise ratio: A number of studies from California and other locations have shown significant changes in physical conditions or biological communities following high flow events. Changes in physical properties are easier to detect, but are often difficult to link conclusively with benefits to the biota of interest. Long-term monitoring programs must have sufficient sampling effort and design focus to detect changes in salmon and steelhead population responses at various life stages and locations, including subsequent adult production and escapement.

Restoration actions: If experimental flow manipulations prove beneficial they could be applied on a regular basis as water supplies were available. While the benefits of a single or series of flow releases may last several years, repeated allocations of water would be required to maintain beneficial results.

Pilot projects or full-scale restoration actions: The reversibility of flow manipulations implies that all could be considered pilot projects. Nevertheless, if flow manipulations provides great benefits, additional resources could be brought to bear to apply the technique to multiple locations.

Acceptable risk of structural change: Manipulations of flow are inherently dynamic and therefore do not require any structural alterations. While some flows may alter channel morphology, flow manipulations are unlikely to have any long-lasting or irreversible impacts. Concern about property damage may limit maximum available flows on some river systems.

Three options considered: The working group discussed three classes of restoration actions, eventually focusing on one action for advancement. During the breakout session it became apparent that a general discussion of flow manipulation in streams was too sterile; instead, specific streams had to be considered. Selecting suitable streams would necessarily involve consideration of issues such as availability of water, adjacent land use, activity of watershed groups, and other issues not addressable by the breakout group. Therefore the streams were selected from the list already available in the Pilot Watershed Acquisition Program report of the Environmental Water Program. This report lists several criteria for selection, including priorities established by the U.S. Fish and Wildlife Service. Although the criteria used are subjective and some are arguable¹, they provided a useful starting point.

The alternative actions discussed were:

- A. *Increase flows for attraction or passage:* This action applies in Mill and Deer Creeks. The principal issue to be resolved is access by adult spring-run salmon to spawning grounds, and successful out-migration of juveniles. At low elevations where these streams enter the Central Valley, low flow over the outwash fans can reduce stage to the point where passage is impeded. There was some discussion about whether passage could be improved through physical alteration of these areas rather than with flow. These streams have diversion dams but no storage reservoirs, and have significant flow from springs that provides cool summer base flows. Flow would have to be augmented through reduction in instream diversions or alteration in their timing.
- B. *Flow releases sufficient to reactivate geomorphic processes:* This action could apply in many streams, but discussion focused on the Tuolumne River and Clear Creek. Flows are greatly reduced in these streams because of dams such that natural geomorphic processes occur only during floods, which come at a greatly reduced frequency. The idea would be to establish a hydrograph that provides either a flow regime close to natural

¹ The PWAP used recommendations for flow augmentation from the ERP Strategic Plan. The origin of these recommendations is uncertain. The Strategic Plan presents an approach for selecting projects from implementation, but this approach has never been applied to any of the specific recommendations that were put in the Strategic Plan. The CALFED Independent Science Board is undertaking a review of the Strategic Plan, and one of its objectives will be to attempt to resolve this inconsistency.

during some seasons, or a “miniaturized natural flow regime”, which would provide some of the natural processes but at a reduced flow and in a smaller physical space. This would require continued augmentation of inputs of gravel and possibly woody debris below the dams, since the geomorphic processes would continually move gravel downstream. This manipulation was described as an “acute” effect, lasting a relatively short time, although effects could last much longer.

- C. *Elevated base flows*: In the Tuolumne River and in many other Central Valley streams, base flows during spawning, incubation, and rearing of salmonids are low. Although it is assumed that increasing base flows would benefit salmonids, there is surprisingly little published evidence to support this assumption. However, regulated tributaries of the Sacramento River with relatively high base flows tend to have higher and less variable salmonid populations than San Joaquin River tributaries with lower base flows. Base flows could readily be elevated in an experimental context. Similarly, maintaining base flows above historic values, such as in Clear Creek in summer, could provide habitat to salmonid runs cut off from their natural, high-elevation habitats. This is a “chronic” problem requiring augmentation of flow over a relatively long period.

Selection of preferred alternative: Each of the three classes of actions has merit, and strong arguments could be (and were) made for each. Advantages and disadvantages of each class of actions are summarized in Table 1.

The principal criteria used for selecting among these alternatives, and among alternative sites, were:

1. Flow ratio (i.e., the proportion by which flow could be augmented)
2. Availability of monitoring data
3. Ongoing research and restoration
4. Institutional support expected from other programs
5. Extensibility of results to other streams and situations
6. Experimental tractability
7. Presence of species of concern
8. Breadth of scope
9. Expected degree of impact if successful
10. Absence of a hatchery, which could confound investigations

All of the actions met most of these criteria to some degree. Action B was selected primarily because of its relatively large scale and broad scope. The group generally agreed that, if this program were successful in developing and implementing real adaptive management, a large-scale, multi-faceted project would have the greatest impact. The lessons learned from such an effort would provide valuable insights that could be transferred to nearly every other stream in the Central Valley. In addition, Action C could be viewed as a subset, or at least as compatible, with B, so that both could be achieved on the same stream.

Restoration and Scientific Objectives: An adaptive management action must have objectives both of the restoration action itself and the accompanying investigations, although these could be

essentially the same. The selected alternative (B) is the most complex, and a hierarchy of scientific objectives addresses physical and biological responses.

Potential restoration objectives are:

1. Reactivate natural geomorphic processes
2. Increase habitat complexity
3. Restore some riparian vegetation
4. Increase spawning success and early growth and survival of salmonids
5. Increase abundance of other native species

Scientific objectives address the following questions:

Geomorphology:

1. Can a scaled down, dynamic alluvial river be recreated on a highly regulated river?
2. How do flow and input of gravel influence the distribution of grain sizes?
3. When gravel is introduced, how do grain size and introduction rates influence geomorphic processes within the river?
4. How does flow influence the interaction of gravel and woody debris?
5. To what extent does that result in habitat complexity?
6. What flow is needed for channel migration and avulsion?
7. What is the relationship between flows and deposition of fine sediment on floodplains?
8. Do high, uncontrollable flood flows eliminate progress made using this approach?

Riparian vegetation:

9. What temporal pattern of flow promotes establishment of riparian vegetation?
10. What is the relationship between flow and scouring of riparian vegetation, and how does it change with morphology of the stream?
11. What flow magnitudes and timing are needed to initiate woody riparian vegetation germination?
12. What flow recession rates following germination flow are needed to allow germinating seedlings to survive to the establishment phase?

Aquatic Invertebrates:

13. How do sediment-mobilizing flows affect the community of aquatic invertebrates?

Spawning and incubation of salmonids

14. What is the relationship between flow and straying?
15. How do flow, temperature, and gravel distribution interact to influence spawning habitat?
16. What flow patterns, including hyporheic conditions, allow for high survival of embryos?

Rearing of salmonids

17. What flow/habitat conditions maximize food supply?
18. What flow/habitat conditions maximize carrying capacity, growth, or survival?
19. What is the effect of varying over-wintering flow on juvenile steelhead?

Migration of salmonids

20. What conditions of flow, temperature, turbidity, and maturity influence early out-migration?
21. What is the contribution of early migrants to salmon populations?
22. Can predation by resident black bass be reduced through flow manipulation?
23. What is the effect of turbidity on migration?

Important points discussed during the sessions: In addition to the above selection, there were a number of points raised that bear on the selection and on the design of the manipulation.

Big vs. small: Restoring a large stream may provide a greater benefit to salmonids. However, small streams are more likely to have high flow ratios (item 1 above), and are more tractable in terms of experimental design, control, and monitoring. The sites selected fall at the low end of this scale.

Fish vs. processes: Although the ERP Strategic Plan favors the use of natural processes in restoration, it is not necessarily clear that these processes provide the most efficient way at restoring species of concern. In particular, the briefing paper for this session (Brad Cavallo) discussed the potential that high flows have to do harm in some streams, and raised the possibility that geomorphic-scale flows might have unanticipated (and potentially undesirable) effects. For example, high flows needed for geomorphic processes may scour redds; thus there are potential conflicts between short-term losses and longer-term benefits. These could be alleviated by suitable timing of the flood flow releases.

Salmonids vs. other endpoints: Although most of the focus was on salmonids, a number of other potential endpoints of restoration were identified. In particular, establishing riparian vegetation could be an additional objective of the manipulation, and it may have additional benefits for endangered species as well as salmonids in the streams. There was also discussion of other native fish, and of aquatic invertebrates.

Species to investigate: The restoration aspect of the action would most profitably focus on listed species or other species of concern. The scientific aspect would benefit from a focus on abundant species. These are not necessarily exclusive, and a stream with both would be ideal.

Experimental endpoints: Although the goals of the restoration relating to salmonids generally target adults, the experimental endpoints should be a variety of measures expected to respond to the flow manipulation. These might include spawning success, habitat area, hatching and emergence success, growth or survival of juveniles, or smolt production. These variables would respond rather quickly to local conditions, whereas adult production or escapement would be subject to substantial sources of variability outside of the manipulated stream.

Passive vs. active adaptive management: On many streams passive adaptive management could be applied using natural variability to provide the contrast necessary to detect effects of flow. The alternatives selected were generally examples of active adaptive management. In fact, a criterion used for selection was the ratio by which flow could be augmented, implying a large scope for control of flow, and therefore the ability to establish reasonable experimental conditions.

Scientific quality vs. restoration importance: This describes several axes of discussion. First, the actions are designed to achieve restoration, and may not satisfy all of the requirements of experimental design. The lack of true replicates among rivers, and the normal temporal variability from many sources, precludes the establishment of a rigorous and thoroughly defensible experiment at the scale of an entire river. Conducting such an action on a small river may provide better control and a greater ability to measure responses, but would have less overall impact both on target populations and on public perception. In addition, the degree to which results could be transferred to other systems varies with the design and with the class of action being considered. This latter point needs to be kept in mind during design of the action.

Multiple opportunities vs. simple experiments: A large-scale manipulation with multiple endpoints could provide a lot of benefit in terms of both restoration and scientific objectives. This would favor the geomorphic alternative (B). However, experimental design calls for manipulation of one or at most a few inputs. Changing many aspects of the system at once will make identification of cause and effect a major challenge. The solution to this may lie in the degree of commitment to the scientific side of the action, such that numerous intermediate variables can be measured for use as endpoints of particular processes.

Miniaturized flows: There was some concern that a miniaturized channel, with flows reduced accordingly, would be vulnerable to the occasional uncontrollable flood. Floodplains or riparian vegetation might help to alleviate these problems, but this remains a significant unknown. The effects of a major flood may reverse a lot of gains, and require remediation.

Key uncertainty: All of these systems are highly variable, even the strongly regulated ones. Measuring the responses of these systems will be a major challenge.

Experimental Design:

Workshop participants did not get far into the design of proposed experiments because of the time it took to distill down the broad range of concepts to the few presented here. An accompanying design document is being prepared by Scott McBain and Frank Ligon, and this will be circulated for review when it becomes available.

Table 1. Summary of advantages and disadvantages of each of the proposed classes of actions

Action	Advantages	Disadvantages
A	Small-scale and tractable Spring-run salmon a listed species that would be affected	Small impact except on spring-run salmon Narrow focus Not very extensible to other locations
B	Large-scale, noticeable Many environmental issues addressed Extensible to several other streams	Geomorphic effects may be undesirable Complicated Large monitoring and research effort required
C	Extensible to many other streams Focuses on a key unknown of salmonid biology	Focuses on salmonids only

Table 2. Advantages and disadvantages of geomorphic-scale flow enhancements in Clear Creek and the Tuolumne River.

Site	Advantages	Disadvantages
Both	Active restoration Chosen by CALFED public process Can design channel to fit flow Some monitoring Will capture people's attention No hatchery	Power costs Monitoring program needs improvement Salmonid stocks of uncertain origin
Clear Creek	Smaller (easier to deal with, measure) Clear (fish are visible for study) Bureau of Rec. gets to recapture the water Population response detectable Restoration closer to historic conditions Decision analysis model available	Smaller (less important to overall restoration) Engineering needed to control flow and to allow flow > 1200 cfs Not very representative of CV streams Mercury a potential issue
Tuolumne R.	Bigger (important to SJ salmon) Good escapement time series Strong relationship of escapement to flow implies strong flow response Results more applicable to other CV streams Two salmon models	Bigger (harder to deal with, measure) Water is more turbid at high flow Gravel pits in lower river Mercury a potential issue

Participants:

Wim Kimmerer (Convenor)
Brad Cavallo (Issue champion)
Craig Stevens (note-taker)
Michael Healey
Serge Birk
Diana Jacobs
Randy Brown
Frank Ligon
Tim Ramirez
Terry Mills
Dan Castleberry
Tom Dunne
John Williams
Scott McBain

Observers:

Diane Windham
Heather Dempsey
Andy Hamilton
Marty Kjeldson
Dick Daniel
Pat Brandes
Jill Marshall (CALFED Science Program)
(others?)